

**UNITED STATES AIR FORCE
311th Human Systems Wing**

**A Survey of Fatigue in Selected
United States Air Force
Shift Worker Populations**

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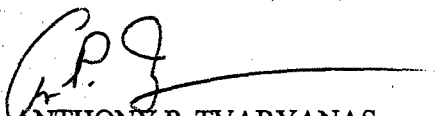
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14. ABSTRACT The purpose of this study was to quantitatively assess fatigue in several United States Air Force (USAF) shift worker populations. An epidemiological cross-sectional survey of 172 USAF personnel was conducted from October 2004 to May 2005. The study sample was recruited from 4 different USAF populations using some form of shift work to include irregular, rotational, or fixed shifts. Self-reported average daily sleep and sleep quality did not correlate with fatigue. Fatigue was greater in the unmannd aircraft versus the manned aircraft squadron irrespective of career field; implying organizational work-related factors such as workload or manpower were underlying this observation. Crewmembers and maintenance personnel reported equal levels of fatigue, suggesting crewmember work/rest guidelines may not be useful for mitigating fatigue associated with shift work. Shift workers were equally fatigued whether at home base or deployed in current military operations, reinforcing the intrinsically fatiguing nature of shift work.					
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EXECUTIVE SUMMARY

Purpose: Quantitatively assess fatigue in several United States Air Force (USAF) shift worker populations.

Background: An Air Force Inspection Agency (2004) assessment of the impact of shift worker fatigue on USAF ground mishaps and operational errors found 12 percent of shift workers interviewed experienced an adverse fatigue-related event although only 31 percent reported the event. This assessment did not include aircrew or contingency operations due to existing aircrew work/rest guidelines and the dynamic nature of contingency operations.

Key Study Areas:

1. Correlation between fatigue and average hours slept.
2. Effect of squadron factors (e.g., work situation) on shift worker fatigue.
3. Effect of presence of work/rest guidelines of shift worker fatigue.
4. Effect of participation in contingency operations on shift worker fatigue.

Methodology: An epidemiological cross-sectional survey of 172 USAF personnel was conducted from October 2004 to May 2005. The study population was recruited from four different USAF organizations using some form of shift work to include irregular, rotational, or fixed shifts: 1) unmanned aircraft system (UAS) crewmembers, 2) UAS maintenance personnel, 3) manned aircraft (MA) crewmembers, and 4) MA maintenance personnel.

Overall Assessment: Based on the data collected, the following were noted:

- Self-reported average daily sleep and sleep quality did not correlate with fatigue, indicating other factors besides sleep modulate shift worker fatigue.
- Fatigue was greater in the UAS versus the MA squadron irrespective of career field, implying organizational work-related factors such as workload or manpower may underlie this observation.
- Crewmembers and maintenance personnel reported equal levels of fatigue, suggesting crewmember work/rest guidelines may not be useful for mitigating fatigue associated with shift work.
- Shift workers were equally fatigued whether at home base or deployed in current military operations, reinforcing the intrinsically fatiguing nature of shift work.

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A SURVEY OF FATIGUE IN SELECT UNITED STATES AIR FORCE SHIFT WORKER POPULATIONS

INTRODUCTION

Background

Many current human-machine operations are continuous in character and the nature of these operations often precludes a temporary shutdown because of economical or other constraints (Kidd & Kinkade, 1959). Such operations have the potential to create situations in which people are driven to work continuously. This has certainly been the case in military operations where technological advances in night vision devices and other sensors coupled with a global battle space has led to a doctrine of continuous, round-the-clock operations (Caldwell, 2003; Krueger, 1989). Such military operations are characterized by circadian disruptions, shift work, sleep loss, and high stress levels which may result in high levels of fatigue and sleepiness while on duty (Simons & Valk, 1999). Serious public health concerns have been raised regarding the association between the documented effects of shift work, such as sleep loss, circadian disruption, and subsequent fatigue, and degraded job performance and an increased risk for errors and accidents (Folkard & Tucker, 2003; Mitler, Dinges, & Dement, 1994; Office of Technology Assessment, 1991). An assessment of the impact of shift worker fatigue on United States Air Force (USAF) ground mishaps and operational errors found 1,018 of 8,339 (12 percent) shift workers interviewed experienced an adverse fatigue-related event although only 31 percent reported the event (Air Force Inspection Agency [AFIA], 2004). This assessment did not include aircrew or contingency operations due to existing aircrew work/rest guidelines and the dynamic nature of contingency operations. The report recommended non-aircrew shift workers would benefit by emulating aircrew work/rest guidelines, implying such regulations successfully mitigated fatigue in shift work. However, a study by the Air Force Safety Center (2002) found fatigue was present in 13 percent of the most serious class of Air Force mishaps occurring during fiscal years 1972-2000, costing the Air Force an estimated 54 million dollars each year (Caldwell, 2003). Furthermore, as illustrated by Barton et al. (1995) in their theoretical model of the effects of work schedules on health and safety (Figure 1), other individual and situational factors have a potential role in modulating the relationship between work schedules and fatigue (Fujino et al., 2001; Jansen, Amelsvoort, Kristensen, Brandt, & Kant, 2003; Kant et al., 2003; Knauth & Hornberger, 2003; Monk, 1994; Taylor, Briner, & Folkard, 1997).

Study Objective

The purpose of this study was to assess fatigue in several USAF shift worker populations to include an analysis of the effects of such factors as work situation (e.g., squadron), presence of detailed work/rest guidelines (e.g., crewmembers versus maintenance personnel), and

participation in contingency operations (e.g., deployed status) using a questionnaire designed to measure several fatigue constructs.

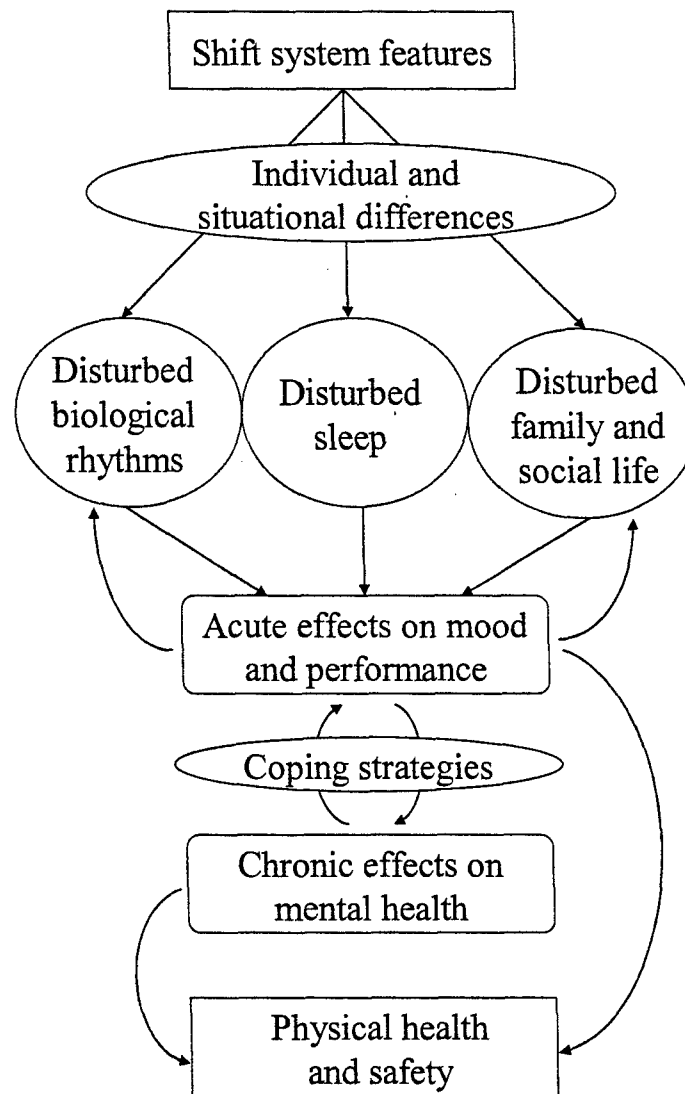


Figure 1. Theoretical model of the effects of work schedules on health and safety (Barton et al., 1995)

METHODS

Study Design and Population

The study protocol was approved by the Brooks City-Base Institutional Review Board in accordance with 32 Code of Federal Regulations (CFR) 219 and Air Force Instruction (AFI) 40-402. The study design was an epidemiological cross-sectional survey of fatigue in a working population conducted from October 2004 to May 2005. The study population was recruited from

four different organizations within the USAF: 1) unmanned aircraft system (UAS) crewmembers, 2) UAS maintenance personnel, 3) manned aircraft (MA) crewmembers, and 4) MA maintenance personnel. UAS crewmembers consisted of MQ-1 Predator pilots and sensor operators operating either from the mission control element (MCE) at Nellis Air Force Base (AFB), Nevada or the launch and recovery element (LRE) at a deployed location in Iraq. The UAS maintenance personnel were MQ-1 maintainers deployed to Iraq. The MA crewmembers consisted of E-3B Sentry airborne warning and control system (AWACS) aircrew flying from Tinker AFB, Oklahoma. The MA maintenance personnel were E-3B maintainers working at Tinker AFB. Shift work was broadly defined as recurrent "work at times other than normal daylight hours of approximately 7:00 A.M. to 6:00 P.M." (Rosa & Colligan, 1998, p. 1411). Personnel in these four organizations were involved in some form of shift work to include irregular, rotational, or fixed shifts. MQ-1 Predator and E-3B Sentry crewmembers were specifically selected for comparison to reduce potential confounding by crew composition (e.g., high prevalence of enlisted crewmembers), mission length and profile, and operations tempo. Participants completed questionnaires after receiving a standardized oral introduction from one of the investigators. Participation was open to all current shift workers.

Fatigue Evaluations

The study questionnaire collected data on age, gender, rank, career field, average daily hours of sleep, and an ordinal rating of quality of sleep. Rank was divided into five categories: junior enlisted, non-commissioned officer, senior non-commissioned officer, company grade officer, and field grade officer. Career field was divided into two categories: crewmember and maintenance. Sleep quality was divided into three categories: excellent, moderate, and poor. Since some view fatigue as a multidimensional construct (Gawron, French, & Funk, 2001; Smets, Garssen, Bonke, & Haes, 1995), this study used a composite fatigue survey (CFS) arranged on a Likert-type scale and composed of items from five validated fatigue questionnaires: the fatigue scale (FS), checklist individual strength concentration subscale (CIS-CON), fatigue assessment scale (FAS), World Health Organization quality of life assessment energy and fatigue subscale (EF-WHOQOL), and Maslach burnout inventory emotional exhaustion subscale (MBI-EE). The 11-item FS distinguishes mental fatigue (four items) and physical fatigue (seven items) in addition to yielding a total fatigue score. This scale is purported to be intended for detection of fatigue cases in epidemiological studies (Chalder et al., 1993). The CIS-CON consists of five items and provides a score for the reduced concentration component of fatigue. The CIS has been shown to discriminate between groups with expected differences in fatigue (Beurskens et al., 2000). The 10-item FAS is a unidimensional fatigue scale developed to assess chronic fatigue (Michielsen, De Vries, & Heck, 2003). The 4-item EF-WHOQOL and 5-item MBI-EE measure the emotional exhaustion component of burnout, the end stage of fatigue experienced over a relatively long period (Barnett, Brennan, & Gareis, 1999; World Health Organization [WHO], n.d.)

Statistical Analysis

Data were analyzed using Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL) version 11.5. Kolmogorov-Smirnov and Shapiro-Wilk tests were used to assess normalcy. Fisher exact tests (FET) and an analysis of variance (ANOVA) with Bonferroni

posthoc testing were used to assess for differences in the baseline characteristics of the study population. A univariate analysis of covariance (ANCOVA) was used to test whether mean daily hours slept differed between three groups: squadron (e.g., UAS versus MA), career field (e.g., crewmember versus maintenance), and environment (home base versus deployed). The categorical variables gender and rank were dummy coded, and along with age, were included as covariates. The results were examined to determine whether there were sphericity violations of sufficient magnitude to warrant the use of Huynh-Feldt adjusted degrees of freedom (dfs). A multivariate analysis of covariance (MANCOVA) was used to test whether the mean scores of these same three groups differed across the five fatigue questionnaires simultaneously. Box's M and Levene's tests were used to assure the multivariate assumptions of equality of covariance matrices and equality of error variances across groups were not violated. The model was unbalanced and type IV sum of squares was utilized. Spearman's correlations were used to test for relationships between mean daily sleep, sleep quality, and fatigue questionnaire scores (Everitt & Dunn, 1991; Harris, 1975; Rosner, 1995).

RESULTS

TABLE 1. Characteristics of study sample.

Variable	Group 1 (UAS crew)	Group 2 (MA crew)	Group 3 (UAS maint)	Group 4 (MA maint)
Number (%) [†]	31 (18)	54 (31)	26 (15)	61 (35)
Age, mean (SD) [‡]	31.4 (7.9)	29.8 (7.4)	27.2 (6.5)	26.9 (7.2)*
Men (%) [†]	25 (81)	42 (81)*	26 (100)	50 (82)
Rank (%) [†]				
Junior enlisted	9 (29)	18 (33)	11 (42)	36 (59)*
Non-commissioned officer	4 (13)	9 (17)	12 (46)*	16 (26)
Senior non-commissioned officer	1 (3)	1 (2)	2 (8)	6 (10)
Company grade officer	9 (29)	19 (35)	1 (4)*	2 (3)*
Field grade officer	8 (26)	7 (13)	0 (0)*	1 (2)*
Deployed (%) [†]	6 (19)	0 (0)*	26 (100)*	0 (0)*

UAS - Unmanned aircraft system, MA - Manned aircraft.

[†]Fisher exact test, [‡]ANOVA with Bonferroni posthoc testing.

*Significant ($p \leq 0.05$) pairwise comparison (versus group 1).

Table 1 shows the baseline characteristics of the 172 participants in this cross-sectional sample. Participants reported a mean (SD) of 6.6 (1.8) hours of sleep per day. There were no univariate effects of squadron, career field, or environment on mean daily sleep, nor were there any significant two-way or three-way interactions. There were also no significant effects based on the covariates age, gender, and rank. Mean daily sleep did not correlate ($\rho = -0.142 - 0.002$)

with scores on the five fatigue questionnaires. Sleep quality was correlated with scores on the EF-WHOQOL ($\rho = 0.183$, $p = 0.034$) and MBI-EE ($\rho = 0.214$, $p = 0.013$).

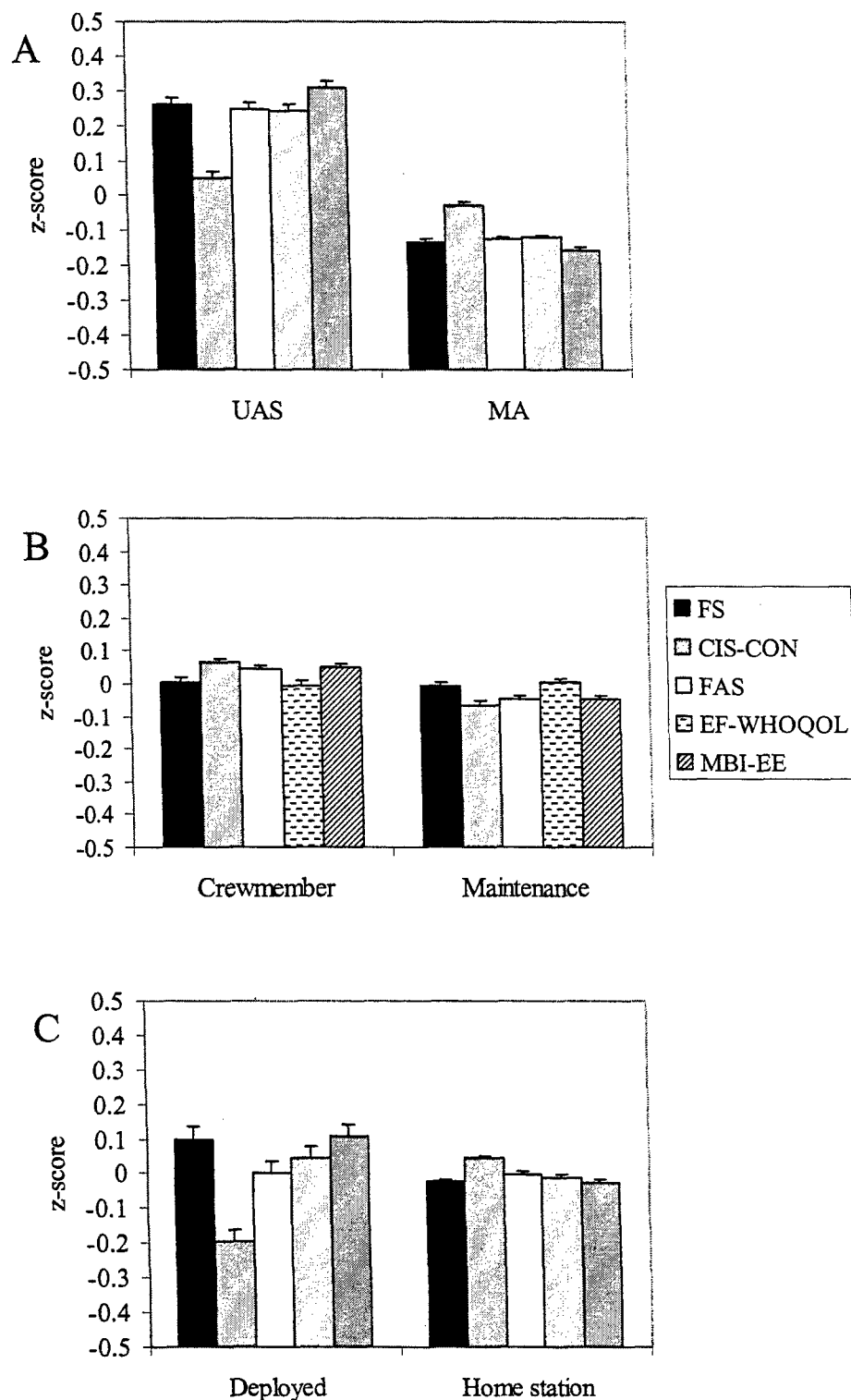
TABLE 2. Characteristics of fatigue questionnaires.

Questionnaire	Mean	SD	Factor loadings	Interscale correlation (range)
CIS-CON	15.500	6.000	0.758	0.466-0.688
EF-WHOQOL	10.642	3.594	0.844	0.466-0.796
FAS	23.752	7.768	0.910	0.627-0.799
FS	28.531	8.545		
Physical fatigue subscale	19.052	6.207	0.894	0.555-0.799
Mental fatigue subscale	9.633	3.271	0.797	0.550-0.677
MBI-EE	18.221	7.166	0.829	0.482-0.744

CIS-CON - checklist individual strength concentration subscale, EF-WHOQOL - World Health Organization quality of life assessment energy and fatigue subscale, FAS - fatigue assessment scale, FS - fatigue scale, MBI-EE - Maslach burnout inventory emotional exhaustion subscale.

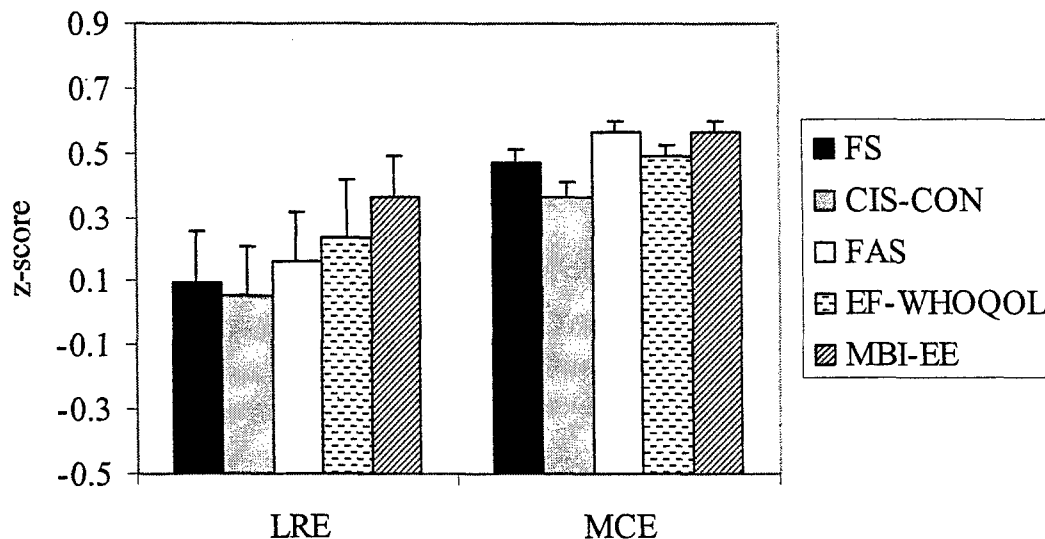
Table 2 summarizes the results from the five fatigue questionnaires. Exploratory factor analysis of the results from the five fatigue questionnaires yielded only one factor, suggesting fatigue is unidimensional with the questionnaires measuring an identical fatigue construct. The factor loadings ranged from 0.758 (CIS-CON) to 0.910 (FAS). A reliability analysis of the five fatigue questionnaires showed good reliability with a standardized Cronbach's alpha of 0.916.

To aid graphical analysis, raw fatigue scores were normalized for each questionnaire to control for the effects of differences in the number of constituent items in each questionnaire on mean scores. Mean scores differed across the five fatigue questionnaires based on squadron (Wilks' $\lambda = 0.916$, $p = 0.017$) (Figure 2A). Mean scores did not differ based on career field (Figure 2B) or environment (Figure 2C), nor were there any significant two-way or three-way interactions. There were also no significant effects based on the covariates age, gender, and rank. Univariate effects based on squadron were found for the FS ($F_{1,159} = 7.567$, $p = 0.007$), FAS ($F_{1,159} = 10.353$, $p = 0.002$), EF-WHOQOL ($F_{1,159} = 9.016$, $p = 0.003$), and MBI-EE ($F_{1,159} = 12.717$, $p < 0.001$) but not for the CIS-CON. Personnel in the UAS squadron had higher FS, FAS, EF-WHOQOL, and MBI-EE scores compared to personnel in the MA squadron. Since crewmembers in the UAS squadron were operating both at home station (MCE) and at a deployed location (LRE), mean fatigue scores were compared between these two subgroups (Figure 3). There were no differences in mean scores between MCE and LRE crewmembers for any of the five fatigue questionnaires although this study was limited in its ability to detect a difference ($\eta_p^2 = 0.042$, power = 0.093).



CIS-CON - checklist individual strength concentration subscale, EF-WHOQOL - World Health Organization quality of life assessment energy and fatigue subscale, FAS - fatigue assessment scale, FS - fatigue scale, MA - manned aircraft, MBI-EE - Maslach burnout inventory emotional exhaustion subscale, UAS - unmanned aircraft system.

Figure 2. Mean fatigue scores by squadron (A), career field (B), and environment (C).



CIS-CON - checklist individual strength concentration subscale, EF-WHOQOL - World Health Organization quality of life assessment energy and fatigue subscale, FAS - fatigue assessment scale, FS - fatigue scale, LRE - launch and recovery element, MBI-EE - Maslach burnout inventory emotional exhaustion subscale, MCE - mission control element.

Figure 3. Mean fatigue scores for unmanned aircraft system crewmembers based on environment.

DISCUSSION

The present study sought to augment the initial USAF assessment of shift worker fatigue (AFIA, 2004) by examining the association of specific risk factors to include work situation, work/rest guidelines, and participation in contingency operations on reported fatigue using standardized and validated fatigue questionnaires. The a priori expectations were for subjective fatigue to be greater in the MA squadron, among maintenance personnel, and for those involved in contingency operations. However, study results differed markedly from these expectations. Working in the UAS squadron was associated with more fatigue while fatigue was equivalent between crewmembers and maintenance personnel as well as those involved in home base vice contingency operations. This study also found fatigue to be a unidimensional construct rather than the multidimensional construct as suggested by AFPAM 91-211 (USAF, 2001) which defines six types of fatigue.

The effect of squadron on mean fatigue scores suggests the presence of systemic work factors in the UAS squadron which predispose to fatigue at work. Such work-related factors could include work content, work relations, work conditions, conditions of assignment, perception of work, professional support, and organizational culture (Kant et al., 2003). While a prior study of UAS crewmembers identified conditions of assignment (e.g., working hours), work conditions (e.g., physical and mental demands), and perceptions of work as potential factors in UAS crewmember fatigue (Tvaryanas et al., 2006), no such analysis of UAS

maintenance personnel has been conducted to date. The lack of any interaction effect based on career field implies the observed higher mean fatigue scores in the UAS squadron were related to work factors independent of the specific task environment. Such factors might include high workloads or inadequate staffing levels, both of which have been shown to enhance the negative effects of shift work (Knauth & Hornberger, 2003). However, further evaluation is required to confirm what those factors may be.

The lack of an effect of career field on fatigue is perhaps one of the most striking findings of this study. This contrasts with the findings by Caldwell and Cornum (1992) that maintenance personnel tended to receive less sleep as defined by actigraphy than crewmembers during an Army National Guard helicopter battalion field exercise, leading them to advocate establishing crewmember-like work/rest guidelines for maintenance personnel. The current study suggests crewmember work/rest guidelines may not mitigate fatigue in the context of shift work and does not support the assertion non-crewmember shift workers would benefit by emulating aircrew work guidelines. The USAF has established maximum flying time limits (USAF, 2005) in order to afford crewmembers sufficient opportunity for recovery from the effects of fatigue, thereby preventing chronic fatigue, chronic job stress, and burnout. The problem with this approach is that it assumes fatigue is highly and positively correlated with time on task in the workplace. However, field research with shift workers as well as laboratory research has consistently demonstrated time-of-day differences in sleep, sleepiness, mood, and performance, indicating that all hours of the day are not equal and interchangeable (Caldwell & Gilreath, 2002; Monk, 1994; National Transportation Safety Board, 1999; Paley & Tepas, 1994). This point was reinforced in a study of shift working UAS crewmembers which found no association between reported fatigue levels and flying time histories (Tvryanans et al., 2006).

The lack of an observed difference in fatigue levels between those involved in home-based versus contingency operations was also surprising. The prevailing expectation is sleep quality and quantity is reduced during contingency operations (Caldwell & Brown, 2003; Caldwell & Gilreath, 2002; Krueger, 1989; Neville, Bisson, French, Boll, & Storm, 1994), especially for those directly involved in combat and combat support operations in Iraq. However, this study found no difference based on deployment status in reported quantity of sleep. Overall, shift work appears to be as intrinsically fatiguing whether the shift worker is at home base or deployed. In fact, the sub-analysis of UAS crewmembers suggests shift work at home base may be even more fatiguing than shift work in a deployed setting. Mean fatigue scores were 6.5-11.1% lower for deployed rather than non-deployed UAS crewmembers. Although this difference was not statistically significant, the study was not adequately powered to detect a difference between these groups raising the potential for type II error (Rosner, 1995). Such a difference would be consistent with the theoretical model of the effects of work schedules since shift work disrupts family and social life (Barton et al., 1995; Colligan & Rosa, 1990; Monk, 1994) and home stress has been shown to correlate with aircrews' perception of job stress and fatigue (Fiedler, Della Rocco, Schroeder, & Nguyen, 2000). Family responsibilities and social pressures leading to intentional sleep restriction (Caldwell, 1997) may be as much a problem as intentional or unintentional sleep deprivation in the operational setting (Krueger, 1989).

Study Limitations

This study used a cross-sectional design which is a fairly quick and easy method for measuring the current health status of populations, but it has the disadvantage of being unable to assess temporal relationships thereby limiting the ability to infer cause and effect relationships. An additional limitation of all fatigue studies is the general lack of a standard way to assess fatigue (Michielsen, De Vries, & Heck, 2003). This study assessed subjective fatigue to include asking participants to report the duration and quality of their sleep. Although subjective estimates of sleep have been shown to perform similarly to actigraphy, both suffer from a wide variation in accuracy between individuals (e.g., random error) when compared to polysomnography (Signal, Gale, & Gander, 2005). Finally, while there are relatively detailed shift work-specific assessment tools (Barton et al., 1995), the composite fatigue survey used in this study was limited to only five relatively short fatigue questionnaires because of the need to limit the impact on participants' time.

CONCLUSION

The goal of evidence-based decision-making is "the systematic application of the best available evidence to the evaluation of options and to decision-making in clinical, management, and policy settings" (Canadian Health Services Research Foundation, 2000, p. 1). To that end, the present study expanded upon an initial USAF assessment of shift worker fatigue (AFIA, 2004) by examining the association of work situation, work/rest guidelines, and participation in contingency operations on reported fatigue using standardized and validated fatigue questionnaires. Shift workers were equally fatigued whether at home base or deployed in current military operations, reinforcing shift work's intrinsically fatiguing nature (Hossain et al., 2004). Organizational work-related factors appeared to best explain the observed differences in fatigue between several USAF shift worker populations. Additionally, crewmembers and maintenance personnel reported equal levels of fatigue, implying crewmember work/rest guidelines are not useful for mitigating fatigue associated with shift work. All of these points serve to highlight the importance of providing formal education and training on sleep hygiene and coping strategies to shift workers, schedulers, and supervisors as well as applying science-based shift scheduling techniques when developing duty time and rest requirements.

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ACRONYMS

AFB	Air Force Base
AFI	Air Force Instruction
AFIA	Air Force Inspection Agency
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
AWACS	Airborne Warning and Control System
CFR	Code of Federal Regulations
CFS	Composite Fatigue Survey
CIS-CON	Checklist Individual Strength Concentration Subscale
DFS	Degrees of Freedom
EF-WHOQOL	World Health Organization Quality of Life Assessment Energy and Fatigue Subscale
FAS	Fatigue Assessment Scale
FET	Fisher Exact Test
FS	Fatigue Scale
LRE	Launch and Recovery Element
MA	Manned Aircraft
MANCOVA	Multivariate Analysis of Covariance
MBI-EE	Maslach Burnout Inventory Emotional Exhaustion Subscale
MCE	Mission Control Element
SD	Standard Deviation
UAS	Unmanned Aircraft System
USAF	United States Air Force